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# Design of CPW-fed Capacitive Coupled Patch Antenna for WiGig Applications

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***ABSTRACT***— *The area of microstrip antennas has seen some inventive work in recent years and is one of the most dynamic fields of antenna theory. The ever increasing need for mobile communication and the emergence of newer technologies require an efficient design of antenna of smaller size for wider frequency range applications such as WiGig. The design, simulation, and characterization of a CPW-fed microstrip antenna capable of covering the entire IEEE 802.11ad (WiGig) frequency band (57–66 GHz) has been presented in this paper. A conductor-backed (CB) coplanar waveguide (CPW)-fed loop slot couples the energy to the patch antenna, resulting in a broad bandwidth. The substrate used here is quartz substrate (□$_{r=3.9,\ \tan\delta=0.0002}$ at 60 GHz), on top of which an SU-8-based three-dimensional (3-D) structure with air cavities has been placed. The patch metallization is deposited on top of this 3-D structure. Simulation of the proposed antenna has been carried out for different geometries and impedance tuning coupling mechanisms. Parametric study was included to determine the effect of design towards the antenna performance. The design was optimized to meet the best possible result. The proposed antenna has also found to be promising to be embedded with devices employing WiGig applications.*

***Keywords***— *Coplanar waveguide (CPW), IEEE 802.11ad, SU-8, WiGig.*

## I. INTRODUCTION

Modern multimedia applications demand higher data rates, and the trend towards wireless is evident. To satisfy the industries requirement in order to get high data rates around 7 Gbit/s, WiGig is an option. Operating at 57-66 GHz bandwidth we can archive this bench mark as per the standard of IEEE 802.11ad [4]. But, bandwidth demands are still rising. In such a context, 60 GHz millimeter wave (MMW) systems constitute a very attractive solution, due to the fact that there is a several GHz unlicensed frequency range available around 60 GHz,[6] almost worldwide. In Europe the frequency ranges 62-63 GHz and 65-66 GHz are reserved for wideband mobile networks MBS, (Mobile Broadband System), whereas 59-62 GHz range is reserved for wideband wireless local area networks (WLAN). In USA and South Korea, the frequency range 57-64 GHz is generally an unlicensed range. In Japan, 59-66 GHz is reserved for wireless communications [4]. This massive spectral space enables densely situated, non-interfering wireless networks to be used in the most bandwidth-starving applications of the future, in all kinds of short-range (< 1 km) wireless communication.

The Wireless Gigabit Alliance (WiGig) was a trade association that developed and promoted the adoption of multi-gigabit speed wireless communications technology operating over the unlicensed 60 GHz frequency band. The WiGig specification allows devices to communicate without wires at multi-gigabit speeds. WiGig enabled devices, deliver data transfer rates up to 7 Gbit/s, about as fast as an 8 antenna 802.11ac transmission, and nearly 50 times faster than the highest 802.11n rate, while maintaining compatibility with existing Wi-Fi devices. The Wireless Gigabit Alliance was formed to provide a single multi-gigabit wireless communications standard among consumer electronics like display and audio applications, handheld devices and PCs, and drives industry convergence using unlicensed ISM (industrial, scientific and medical) 60 GHz spectrum.

## II. ANTENNA DESIGN

The main aim behind this antenna design is to implement with low cost and good impedance matching at millimetre wave lengths. It's a task to design antenna at mm wave frequencies because of its smaller dimensions. The role behind the CPW- fed is to have low radiation loss, less dispersion, easy integration for monolithic microwave circuits (MMICs) and a simple configuration with single metallic layer, since no backside processing is required for integration of devices [2]. Therefore, the designs of CPW-fed antennas have recently become more and more attractive. One of the main issues with CPW-fed antennas is to provide an easy impedance matching to the CPW-fed line. In order to obtain multiband and broadband operations, several techniques have been reported in the literatures based on CPW-fed slot antennas [3].

**Design specifications**

The substrate used here is quartz ($\varepsilon_{r=3.9,\ \tan\delta=0.0002}$ at 60 GHz). For enhanced band width, quartz is used as a substrate. On top of that su-8 structure with air cavities are designed. In order to create thick enough substrates, SU-8 ($\varepsilon_{r=3.1,\ \tan\delta=0.021}$) [7], is an excellent choice [1]. However, its high loss tangent is the drawback for using it as a dielectric for planar antennas. Techniques such as creating holes, air cavities, etc., reduce the effect of dielectric loss on the antenna performance [8]. Combining the advantages of SU-8 along with these techniques yields an antenna substrate that is both electrically and mechanically an efficient solution. Hence, in this paper, micro fabricated SU-8-based three-dimensional (3-D) structures with air cavities are used as low-loss alternative substrates for WiGig antennas. Table I shows the design parameters of CPW-fed capacitive coupled patch antenna.

**TABLE I. DESIGN PARAMETERS**

| Parameters | Dimensions |
|---|---|
| Center rectangular dimensions | 0.8mm x 2mm |
| Center feed line dimensions | 3.5mm x 0.191mm |
| Substrate | 7mm x 7mm x 525um |
| Bottom cu ground | 7mm x 7mm x 0.03mm |
| Top cu ground | 7mm x 7mm x 0.03mm |
| Su-8 structure posts | 600um x 750um x 0.2mm |
| Su-8 top dimensions | 2.6mm x 7mm x 0.1mm |

## III. RESULTS AND DISCUSSIONS

In this section, the performance of the proposed antenna is demonstrated through its simulated results. The simulated results in term of return loss, radiation pattern has been exhibited and illustrated.

The antenna as depicted in Fig. 1(a) is a CPW-fed broadband patch antenna on an RF-compatible quartz substrate. The feed metallization, which consists of a CB CPW, along with the loop is formed on a 525-µm thick quartz substrate. The 3-D substrate consists of an SU-8 membrane that is supported via SU-8 posts. The patch antenna metallization is finally formed on this 3-D substrate.

The location of SU-8 posts and the thickness of SU-8 photo resist membrane dictate the mechanical stability of the 3-D antenna. As SU-8 is quite lossy, an intelligent design tradeoff between the mechanical integrity of the 3-D structure and the performance of the antenna needs to be incorporated. Accordingly, air cavities are incorporated in the 3-D SU-8 substrate to reduce the dielectric loss, which would in turn enhance the performance of the antenna. The height of the air cavity, which is also the height of SU-8 posts, has an effect on the impedance BW and realized gain of the antenna [1].

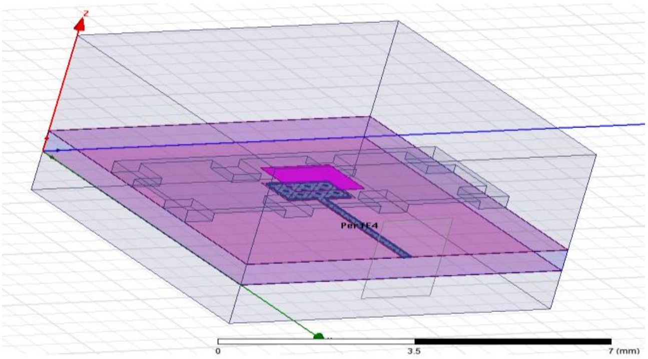


Fig. 1(a) Simulation model of CPW fed Rectangular Patch Antenna

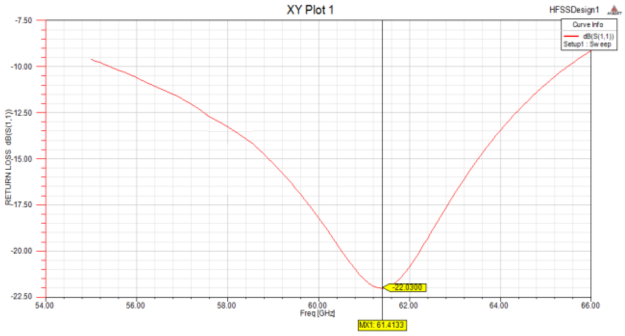


Fig. 1(b) Return loss plot of CPW fed Rectangular Patch Antenna

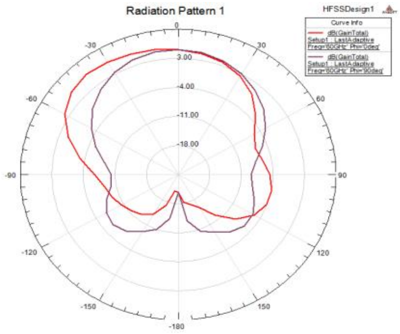


Fig 1(c) Gain radiation pattern of CPW fed Rectangular Patch Antenna

Fig. 1(a) shows the simulation model of rectangular shape CPW fed microstrip antenna for WiGig applications. Fig 1(b) shows the return loss plot and Fig 1(c) shows the gain plot for CPW fed Rectangular patch antenna. From Fig 1(b), it can be observed that the resonant frequency of the patch is 61.41GHz and the value of return loss at the resonant frequency is -22.03dB. Also, the bandwidth of the patch is approximately 10 GHz, at -10dB points [10].

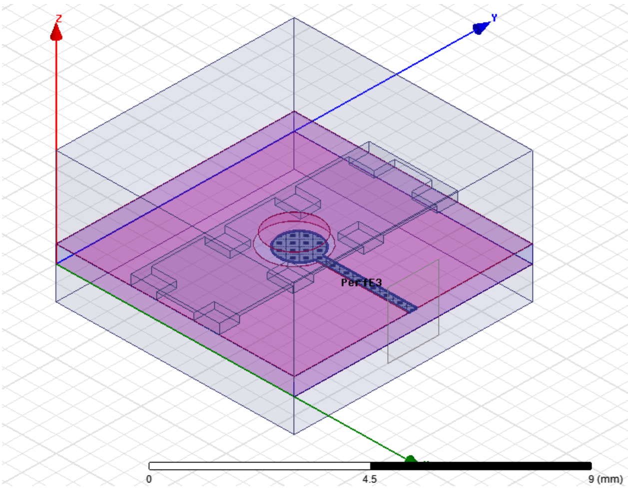


Fig. 2(a) Simulation model of CPW-fed Circular Patch Antenna

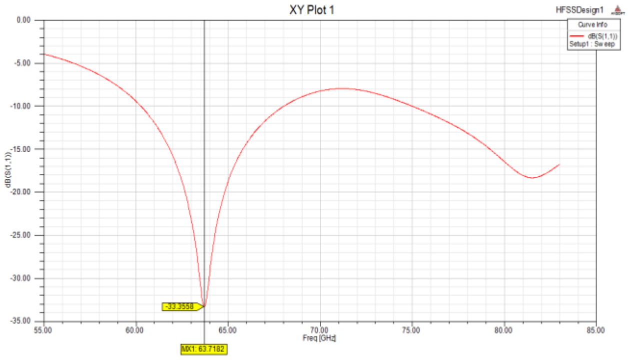


Fig. 2(b) Return loss plot of CPW-fed Circular Patch Antenna

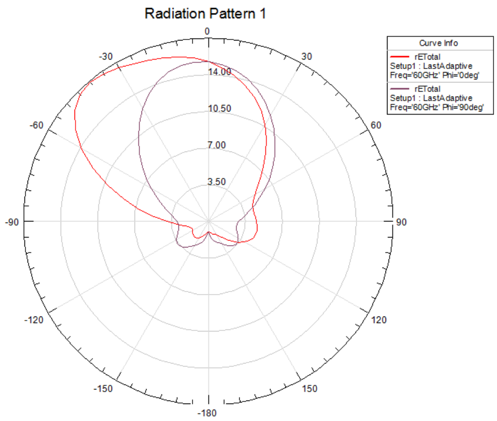


Fig. 2(c) Gain radiation pattern of CPW fed Circular Patch Antenna

Fig. 2(a) shows the simulation model of Circular shape CPW fed microstrip antenna for WiGig applications. Fig 2(b) shows the return loss plot. From the Fig 2(b), it can be observed that the stimulated antenna resonates at 63.41GHz with return loss of -33.3 dB and bandwidth of the patch antenna at -10dB points is approximately 7.8 GHz. Also, the resonant frequency for CPW-fed circular antenna shows an upward shift. Fig 2(c) shows the gain plot for CPW fed Rectangular patch antenna. From the radiation pattern it can be observed that circular CPW fed circular patch antenna has found to be more directional than rectangular shape CPW-fed antenna [10].

**TABLE III**

**COMPARISON OF CPW-FED PATCH ANTENNA WITH VARIOUS GEOMETRIES**

| **Antenna type** | **Return loss ($S_{11}$)** | **Peak gain** | **Peak Directivity** | **Front to Back Ratio** |
|---|---|---|---|---|
| Rectangular shape | -18.20dB | 4.514 | 4.356 | 74.62 |
| Circular shape | **-34.16dB** | **5.663** | **5.516** | **79.15** |

Table II gives the comparative analysis of CPW fed rectangular patch antenna and circular patch antenna in terms of various antenna parameters such as return loss, peak gain, directivity and front to back ratio. It can be observed that circular CPW fed Circular patch antenna has found to be more superior than rectangular shape CPW-fed antenna interms of all the parameters.

One of the main issues with CPW-fed slot antennas is to provide an easy impedance matching to the CPW line [8]. So far, several impedance tuning techniques based on a change of slot dimensions, coupling mechanism or both have been reported in the literatures [9]. Hence, the design of CPW-fed patch antenna with various coupling mechanisms has also been simulated and presented.

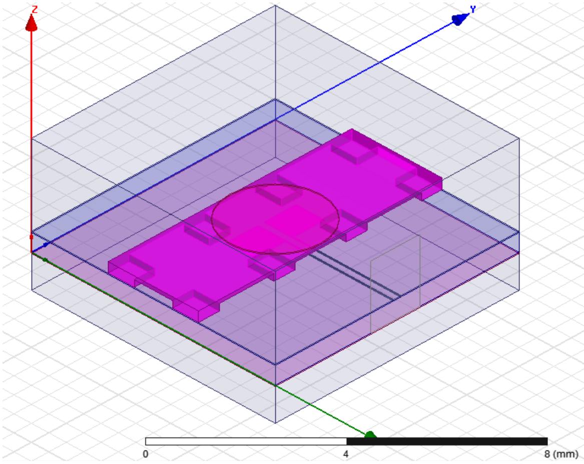


Fig. 3(a) Simulation model of CPW-fed patch antenna with Inductive coupling

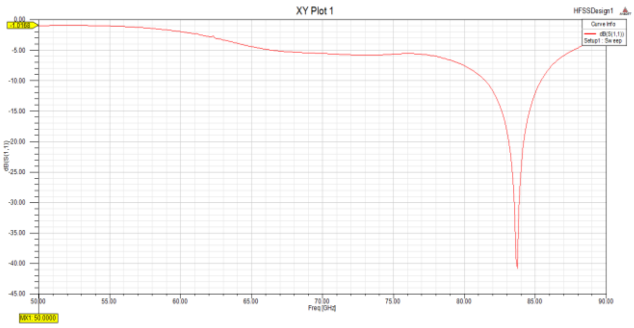


Fig. 3(b) Return loss plot of CPW-fed patch antenna with Inductive coupling

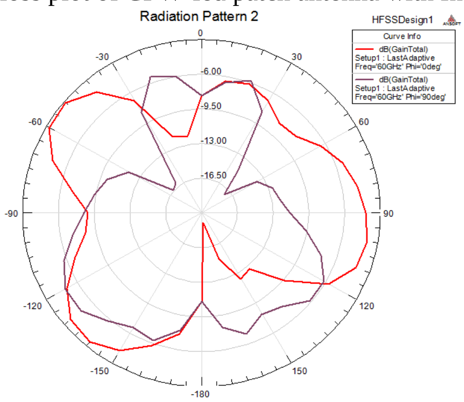


Fig. 3(c) Gain radiation pattern of CPW-fed patch antenna with Inductive coupling

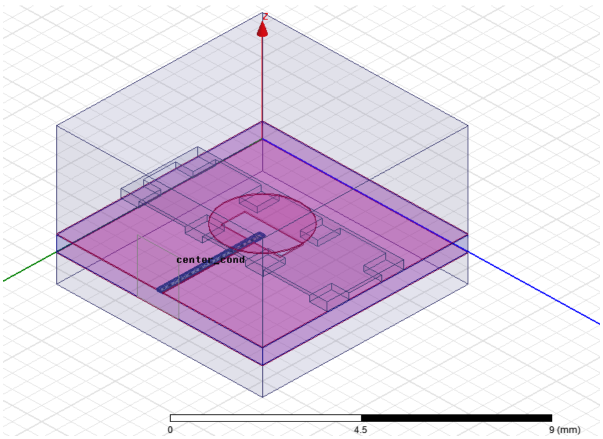


Fig. 4(a) Simulation model of CPW-fed patch antenna with capacitive coupling

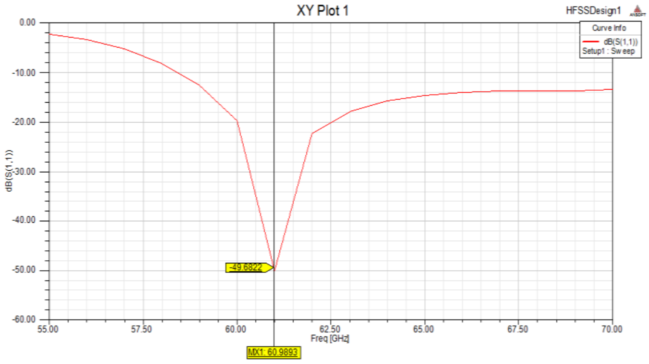


Fig. 4(b) Return loss plot of CPW-fed patch antenna with capacitive coupling

Fig. 3(a) shows the simulation model of inductive coupled CPW fed microstrip antenna for WiGig applications and Fig 3(b) shows the return loss plot. It can be observed that the resonant frequency of the patch is 83GHz and the value of return loss at the resonant frequency is -40.03dB. Fig. 4(a) shows the simulation model of capacitive coupled CPW fed microstrip antenna for WiGig applications. From Fig. 4(b), it can be observed that the patch antenna resonates at 60GHz with a return loss of -50.03dB. . Also, the resonant frequency for CPW fed antenna shows an upward shift. Fig. 3(c) and 4(c) it can be seen that capacitive coupled antenna has high directivity than inductive coupled antenna.

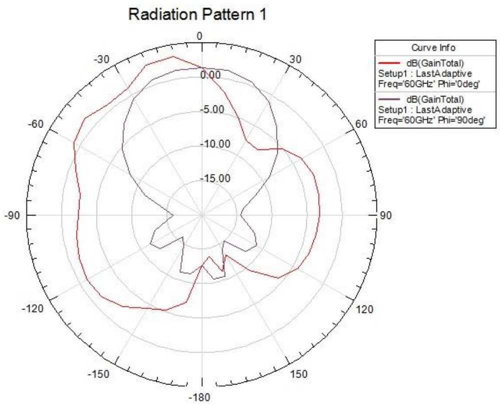


Fig. 4(c) Gain radiation pattern of CPW-fed patch antenna with capacitive coupling

**TABLE IIIII**

**COMPARISON OF CPW-FED PATCH ANTENNA WITH VARIOUS COUPLING MECHANISMS**

| **Antenna type** | **Return loss ($S_{11}$)** | **Peak gain** | **Peak directivity** | **Front to Back Ratio** |
|---|---|---|---|---|
| Capacitive coupling | **-49.68 dB** | **2.143** | **2.039** | **50.761** |
| Inductive coupling | -24.68 dB | 0.937 | 0.88 | 2.191 |

Table III gives the comparative analysis of CPW fed capacitive coupling antenna and inductive coupling antenna in terms of various antenna parameters such as return loss, peak gain, directivity and front to back ratio. It can be observed that capacitive CPW fed patch antenna has found to be more superior than inductive coupling CPW-fed antenna interms of all the parameters. Hence, it can be concluded that capacitive coupled is suitable for WiGig applications. However, inductive coupling is suitable for next generation high speed wireless communication operating at 120GHz.

## IV. CONCLUSION

Wireless communications have progressed very rapidly in recent year and many mobile units are becoming smaller and smaller. To meet the miniaturization requirement, the antennas employed in mobile terminals must have their dimensions reduced accordingly. Planar antennas, such as microstrip and printed antennas, have the attractive features of low profile, small size, and conformability to mounting hosts.

In this paper, a CPW-fed broadband patch antenna compatible with IEEE 802.11ad standard (WiGig) has been designed, and characterized. Extensive simulations have been carried for various shapes and impedance matching coupling mechanisms to study the performance of antenna. Analysing the results, it has been observed that, in terms of geometry circular is more effective and capacitive coupling in terms of impedance matching coupling mechanisms. Hence, it can be concluded that CPW-fed capacitive coupled circular patch antenna is most promising to be embedded in devices employing WiGig applications as it provides a lesser return loss of -49.68dB and optimum directivity value of 2.039.

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